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ARMY COMBAT SYSTEMS TEST ACTIVITY (PROV) ABERDEEN
PROVING GROUND MD W S WALTON NOV 84 USACSTA-6109

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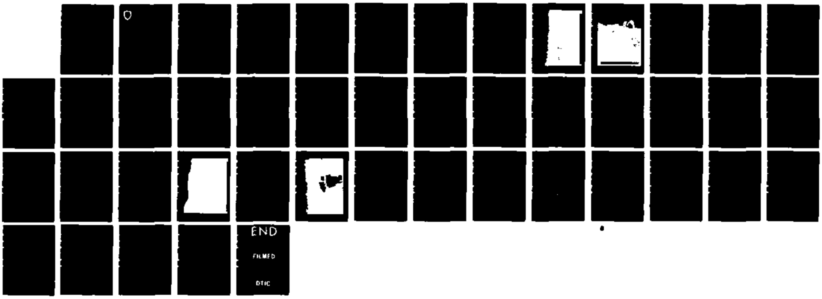

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TECOM PROJECT NO. 7-CO-OM4-APO-002

REPORT NO. USACSTA-6109

FINAL REPORT

INTERNATIONAL WEAPON BLAST OVERPRESSURE EXPERIMENT

W. SCOTT WALTON

MEASUREMENT AND ANALYSIS DIRECTORATE

US ARMY COMBAT SYSTEMS TEST ACTIVITY
ABERDEEN PROVING GROUND, MD 21005-5059

NOVEMBER 1984

Period Covered:
June to November 1984

Prepared for:
US ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MD 21005-5055

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1. REPORT NUMBER TECOM Project 7-CO-OM4-APO-002	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INTERNATIONAL WEAPON BLAST OVERPRESSURE EXPERIMENT		5. TYPE OF REPORT & PERIOD COVERED Final, June to November 1984
		6. PERFORMING ORG. REPORT NUMBER USACSTA-6109
7. AUTHOR(s) W. Scott Walton		8. CONTRACT OR GRANT NUMBER(s) Not available
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Combat Systems Test Activity ATTN: STECS-MA-I Aberdeen Proving Ground, MD 21005-5059		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Not available
11. CONTROLLING OFFICE NAME AND ADDRESS Commander, TECOM ATTN: AMSTE-AD-M Aberdeen Proving Ground, MD 21005-5055		12. REPORT DATE November 1984
		13. NUMBER OF PAGES 42
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) None		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE None

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited.

DISTRIBUTION STATEMENT A
Approved for public release;
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

None

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Air blast overpressure
Muzzle blast
Overpressure measurement
Explosive blast
Transducers

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Blast overpressure measurements were made at the Defence Research Establishment Valcartier (DREV), Quebec, Canada, 10 to 20 October 1984, at positions near: (a) 105-mm L5 howitzer firing charge 7; (b) 84-mm Carl Gustaf antitank weapon; (c) 110-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert, (d) 410-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert. This report describes the measurements made by US Army Combat Systems Test Activity (USACSTA). A complete report describing all measurements made by the five teams representing the United States, Canada, and the United Kingdom will be

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20. prepared by the Defence Research Establishment Valcartier. During this test, large gage-to-gage variations were noticed in the USACSTA transducers. These variations were present only in the first 200 microseconds of the measurements.

DEPARTMENT OF THE ARMY
U.S. ARMY COMBAT SYSTEMS TEST ACTIVITY Mr. Walton/les/283-4318
ABERDEEN PROVING GROUND, MARYLAND 21005-5059

REPLY TO ATTENTION OF

21 November 1984

STECS-MA-I

SUBJECT: Final Report of International Weapon Blast Overpressure Experiment, TECOM Project No. 7-CO-OM4-APO-002, Report No. USACSTA-6109

US Army Test and Evaluation Command
ATTN: AMSTE-AD-M

1. REFERENCES

a. TECOM Regulation 70-12, 1 June 1973, with Change 2.

b. Letter, DRSTE-AD-M, TECOM, 19 January 1984, subject: Test Directive, International Weapon Blast Overpressure, TRMS No. 7-CO-OM4-APO-002.

2. BACKGROUND

Firing restrictions or even acceptance or rejection of a large caliber weapon are often based on blast overpressure measurements; therefore, there is considerable international interest in the accuracy of these measurements. A joint blast overpressure experiment was proposed and hosted by the Defence Research Establishment Valcartier (DREV), under the sponsorship of The Technical Cooperation Program (TTCP) subgroup W (Conventional Weapons Technology), Technical Panel W-2 (Launch and Flight Dynamics), Key Technical Area 7 (KTA-7). In this experiment, five teams, representing the US, UK, and Canada made blast overpressure measurements at positions near the following sources of blast overpressure:

a. 105-mm L5 howitzer firing charge 7.

b. 84-mm Carl Gustaf antitank weapon.

c. 110-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert.

d. 410-gram bare spherical charge, 25.2% RDX, 58.8% PETN, 16% inert.

3. TEST OBJECTIVE

Measure blast overpressure at levels experienced in crew positions of large caliber weapons. Make these measurements under controlled conditions so that the results of each of the five teams can be compared.

4. SCOPE

A complete report describing the results obtained by the five teams will be prepared by DREV. This report will discuss only the results obtained by the US Army Combat Systems Test Activity (USACSTA).

5. SUMMARY OF RESULTS

a. This experiment provided a unique opportunity for multilateral exchange on experimental technique and an excellent test of instrumentation accuracy.

b. Overpressure levels in the operator positions of the two weapons exceeded the current US Army human tolerance criteria.

c. Large gage-to-gage variations (20%) were noticed on the USACSTA transducers during the bare charge tests even though the round-to-round variations were small (3%). These variations were present only during the first 200 microseconds of the signal.

6. CONCLUSIONS

a. This experiment provided a significant first step toward international standardization of weapon overpressure measurement.

b. Although the large gage-to-gage variation is within the ±10% value estimated earlier, steps should be taken to improve accuracy.

7. RECOMMENDATION

A methodology study should be conducted to improve the accuracy of blast overpressure measurements.

FOR THE COMMANDER:

Palmer K Parker
for JAMES W. FASIG
Director, Measurements and
Analysis Directorate

3 Encl
1. Details of Test
2. References
3. Distribution List

DETAILS OF TEST

1. BARE CHARGE TESTING

Bare spherical explosive charges were fabricated by DREV using 25.2% RDX, 58.8% PETN, and 16% binder by weight. Two size charges, 110 and 410 grams, were used. Transducers were placed in a circle around the charge, at a distance of 4.000 ± 0.005 meters from the charge.

Figure 1-1 is a photograph showing the firing site and the circle of transducers around the charge. Figure 1-2 shows the technique used to suspend the charge and locate the center of the charge accurately.

Figure 1-3 illustrates a typical overpressure measurement from the 110-gram charge. Figure 1-4 shows the overpressure from a 410 gram charge. Figure 1-5 illustrates that the arrival time for the 110 gram bare charge is approximately 8.5 ms.

1 (Cont'd)

Figure 1-1. Test area at DREV. Transducers are positioned at 4 meters in preparation for a bare spherical charge detonation.

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Figure 1-2. Photograph of technique used to hang charge and ensure the location accuracy of charge center to ±2 mm.

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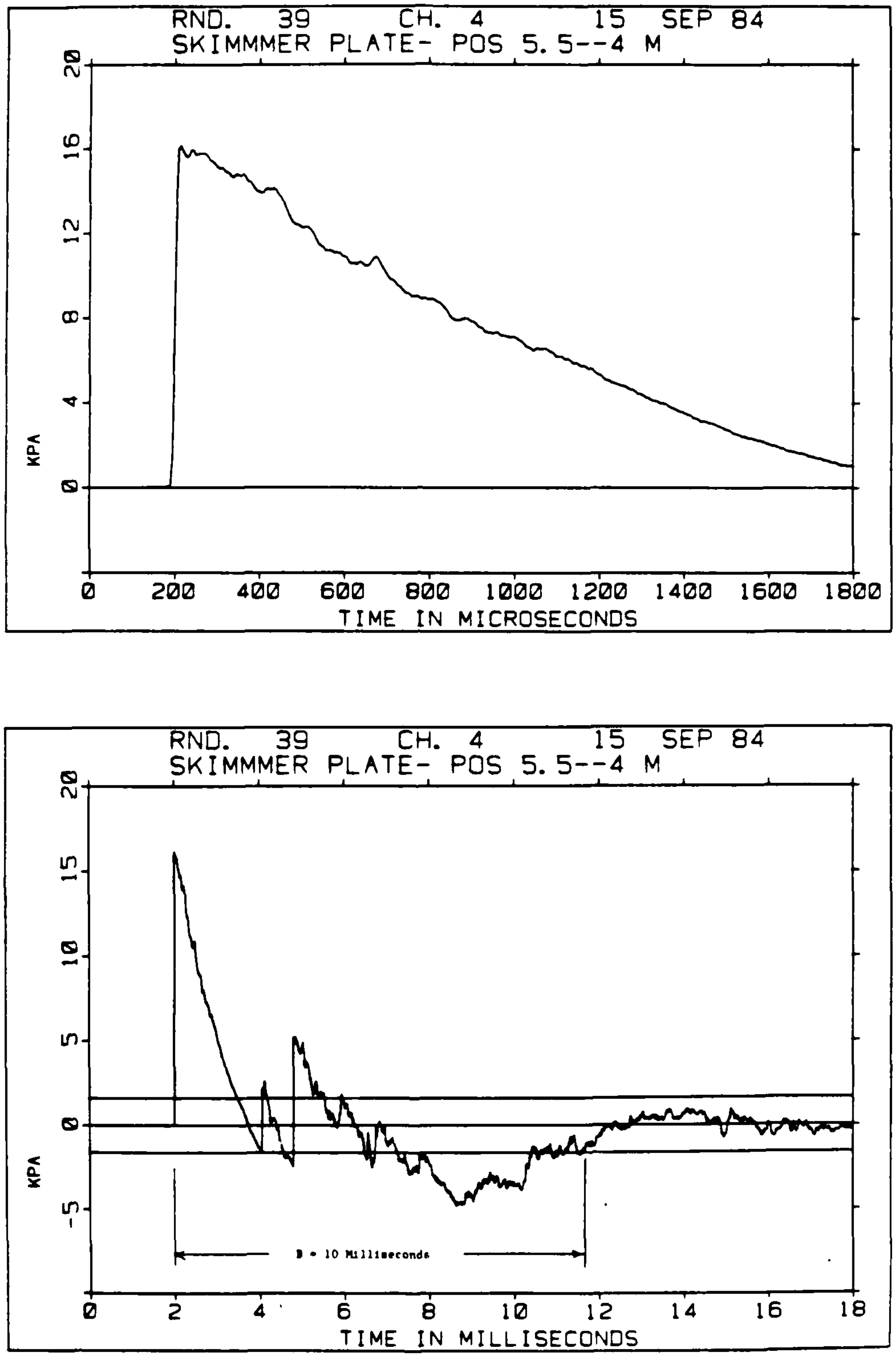

Figure 1-3. Example of blast overpressure at 4 meters from 110 gram bare spherical charge. Upper trace shows details of initial 1.8 ms. Measurement made with PCB102M66 transducer mounted in skimmer plate.

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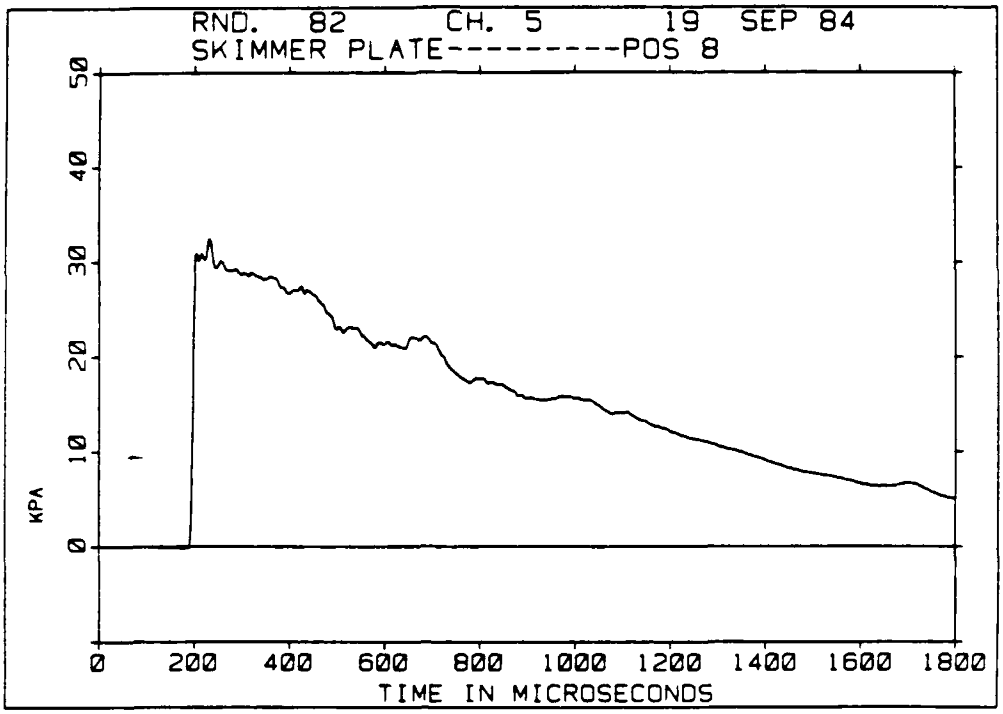

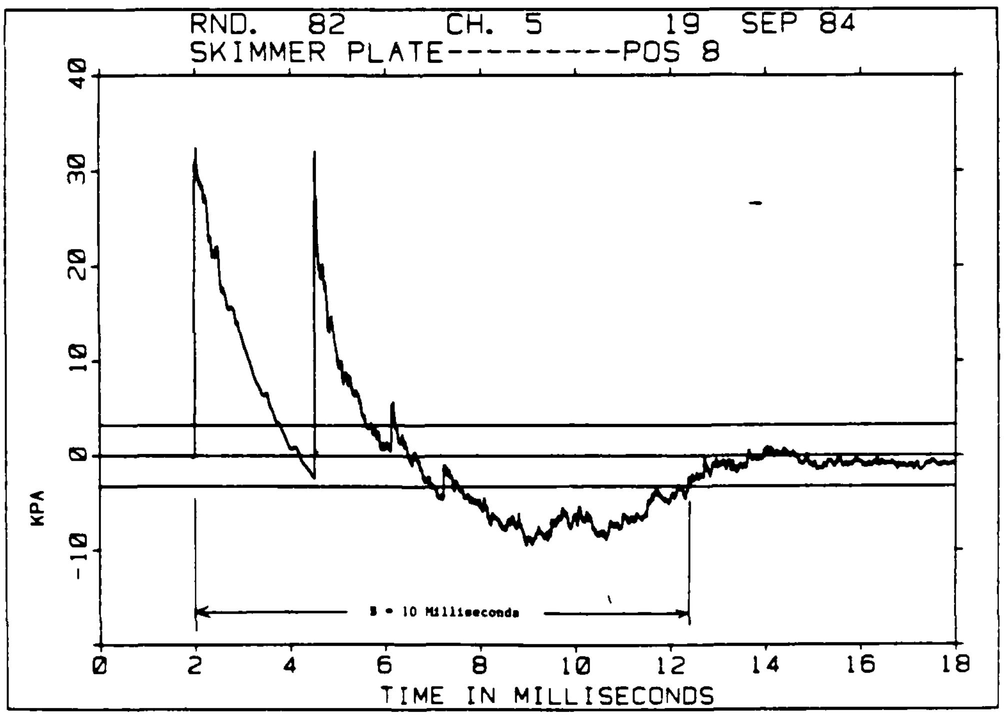

Figure 1-4. Example of blast overpressure at 4 meters from 410 gram bare spherical charge. Upper trace shows detail of initial 1.8 ms. Measurement made with PCB102M66 transducer mounted in skimmer plate.

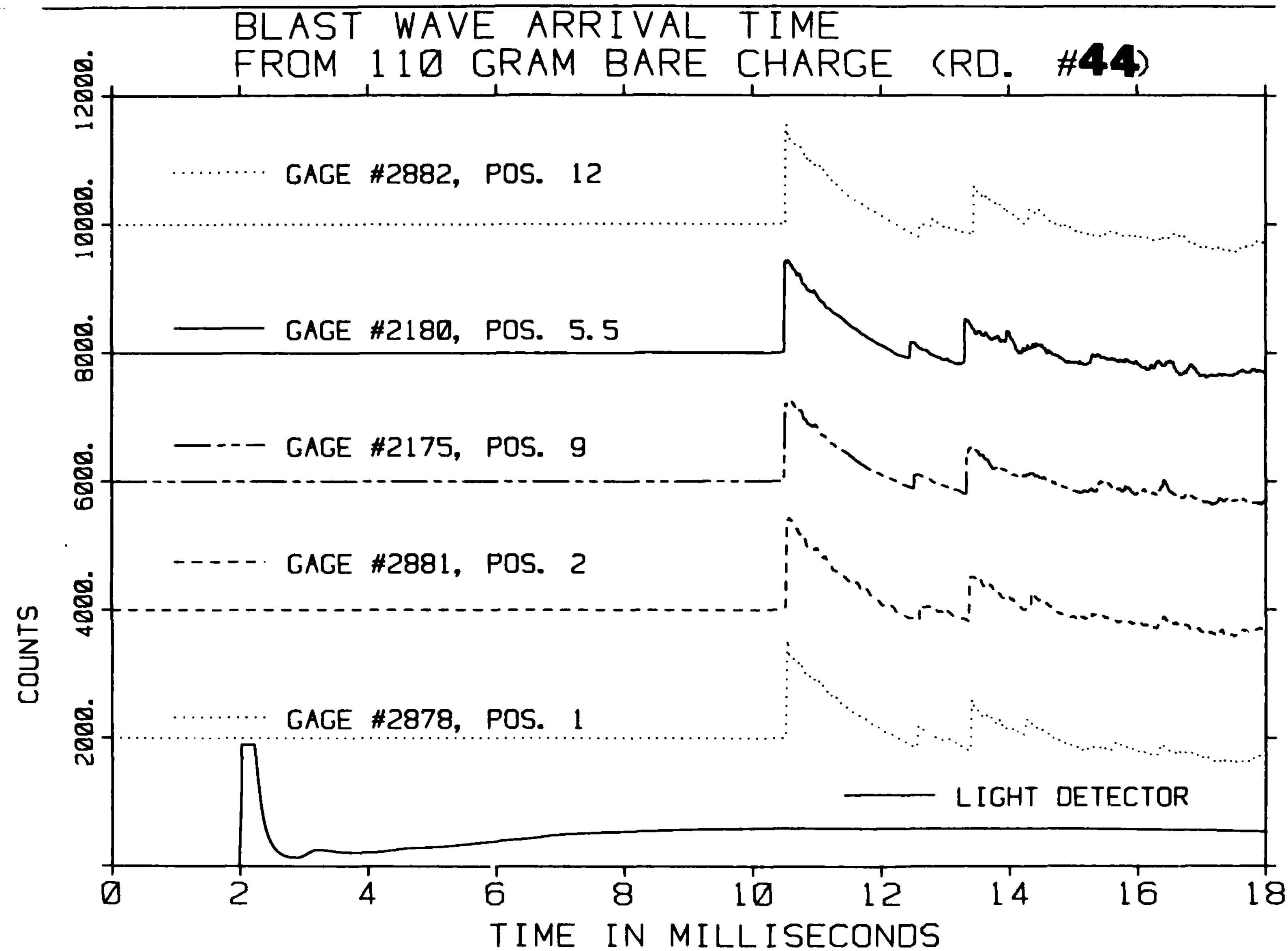

Figure 1-5. Blast wave arrival at 5 positions, all located 4 meters from 110 gram bare spherical

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As shown in Table 1-1, the measured peak pressure, impulse, arrival time, and duration compare favorably with values calculated by Soroka (encl 2, ref 1) based in Goodman's (encl 2, ref 2) data for pentolite.

TABLE 1-1. COMPARISON OF MEASURED BLAST OVERPRESSURE WITH THEORETICAL VALUES FOR PENTOLITE

110 Gram Bare Spherical Charge

Mean	Maximum	Minimum	Theoretical
Peak overpressure in KPa			
16.02	18.01	14.80	15.72
Impulse in KPa (ms)			
11.40	12.17	10.64	12.29

Maximum	Minimum	Theoretical
Arrival time in ms		
8.690	8.362	8.306
Duration in ms		
1.84	1.66	1.69

410 Gram Bare Spherical Charge

Mean	Maximum	Minimum	Theoretical
Peak overpressure in KPa			
33.34	36.26	30.12	30.37
Impulse in KPa (ms)			
26.46	29.11	24.88	28.81

Maximum	Minimum	Theoretical
Arrival time in ms		
7.245	7.023	7.031
Duration in ms		
2.37	2.05	2.17

1 (Cont'd)

Rounds 39 to 43 were a 5-shot group of 110 gram charges. No changes to the transducers were made during this group. As shown in Figures 1-6 through 1-8, the round-to-round repeatability of any one transducer was excellent (3% or less extreme spread).

When one transducer is compared to another, as shown in Figure 1-9, the difference in peak pressure is 15%. Note that approximately 200 ms after the shock wave arrives, the two signals agree perfectly. Hence the large gage-to-gage discrepancy is not caused by calibration error.

Considerable care was exercised in positioning the transducers to the 4 meter distance and alining then to within 1° of the center of the charge. Removing a transducer from the tripod on one day and then replacing on another day resulted in the 11% discrepancy shown in Figure 1-10. Figure 1-11 shows removal of the tape from transducer No. 2180 which caused a discrepancy of 6%.

Two different mounting configurations were used for the bare charge tests. A skimmer plate mount and a blunt cylinder mount, as described by Walton (encl 2, ref 3) were utilized. Higher peak pressures were obtained with four of the six transducers using the blunt cylinder mount as shown in Figure 1-12. Reasonable agreement between the blunt cylinder and the skimmer plate was obtained with two of the six transducers, as shown in Figure 1-13. Figure 1-14 shows excellent agreement between the skimmer plate and the blunt cylinder, but note that different transducers are used.

The reasons for the variations in peak pressure are not understood at this time. The sensitivity of the PCB transducer to variations in mounting configurations has been discussed earlier by Clare and Clare (encl 2, ref 5).

A 1-mm layer of room temperature vulcanizing silicone rubber (RTV) was applied to transducer No. 2883 for extra thermal protection as recommended by Reference 4 of Enclosure 2. As shown in Figure 1-15, this coating increased the rise time and caused some artifacts in the signal. It is felt that the small artifacts observed are preferable to the large offset caused by the high thermal energy environments that require RTV protection.

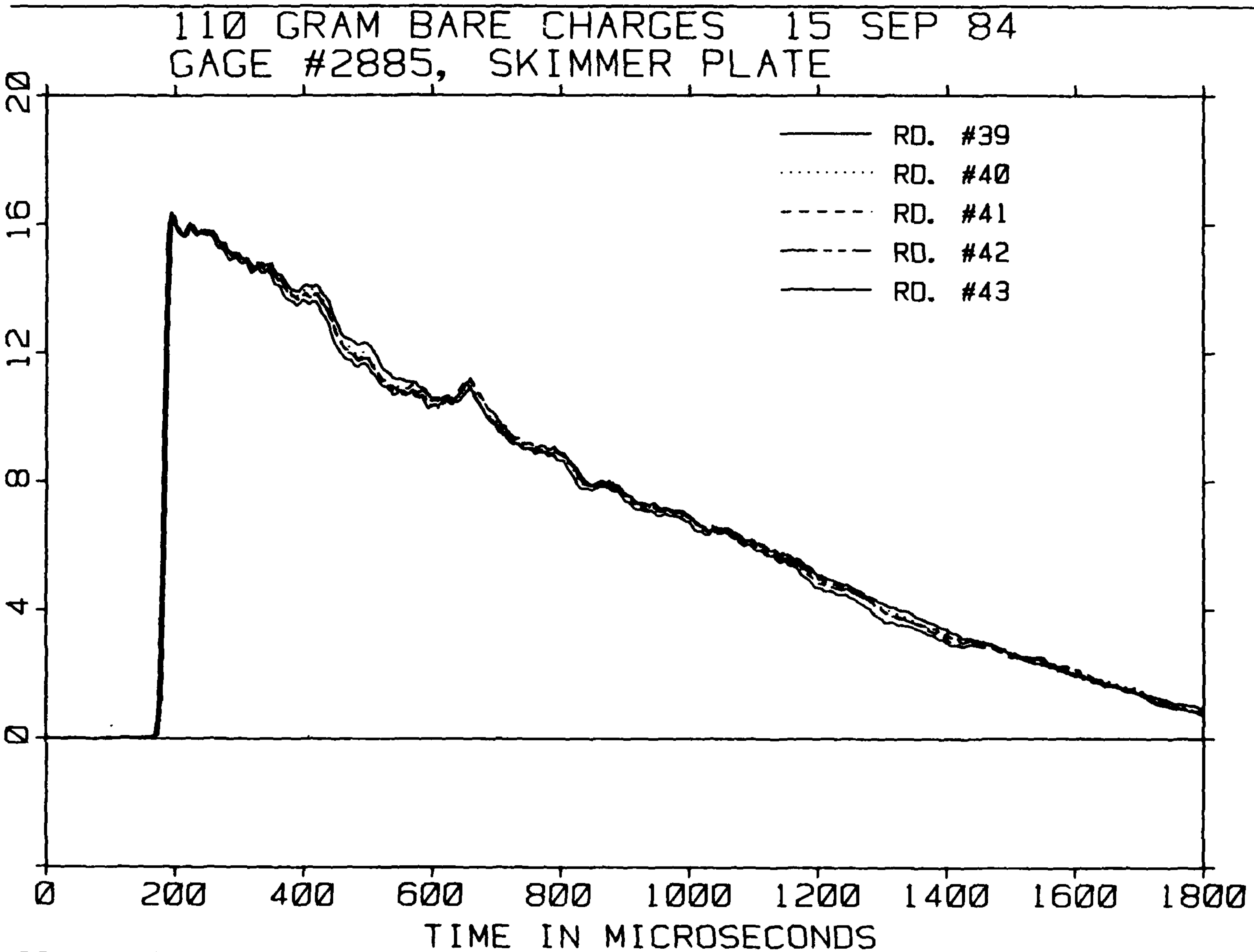

Figure 1-6. Blast overpressure from 5-round group of 110 gram bare spherical charges as measured by transducer

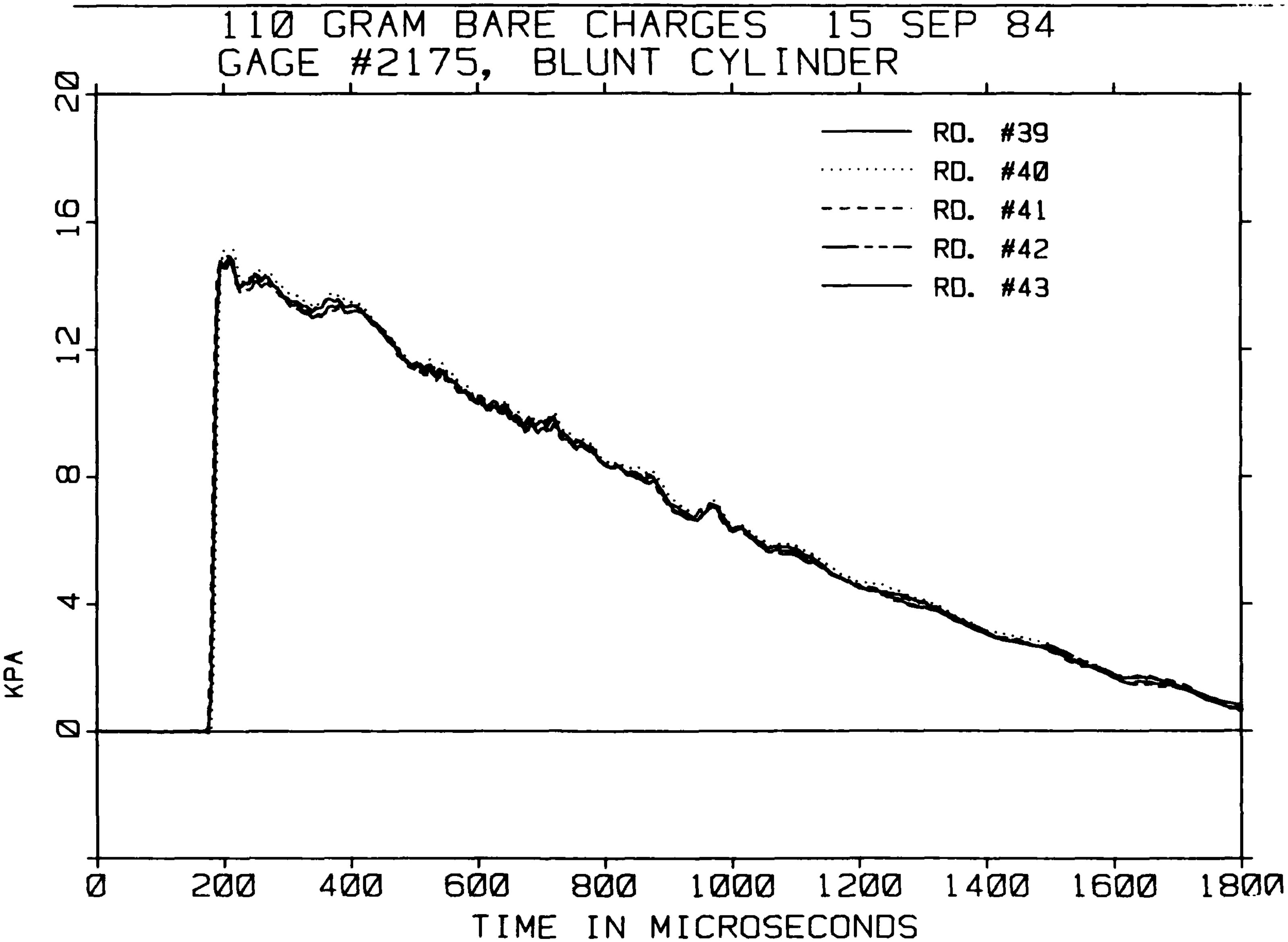

Figure 1-7. Blast overpressure from 5-round group of 110 grams bare spherical charges as measured by transducer No. 2175. Notice that the extreme spread of peak pressure is approximately 2.3%.

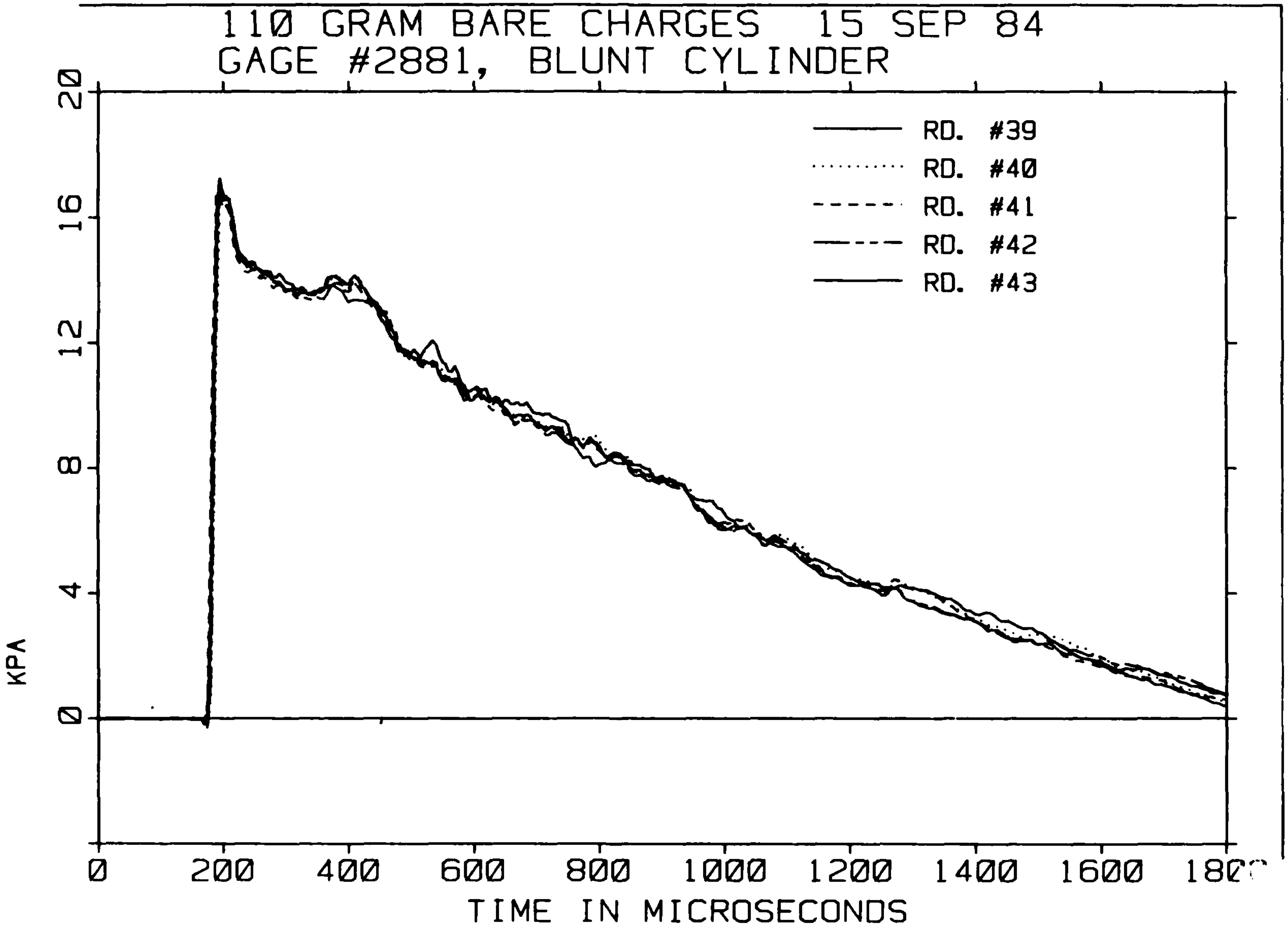

Figure 1-8. Blast overpressure from 5-round group of 110 gram bare charges as measured by transducer No. 2881. Notice that the extreme spread in peak pressure is approximately 3.4%.

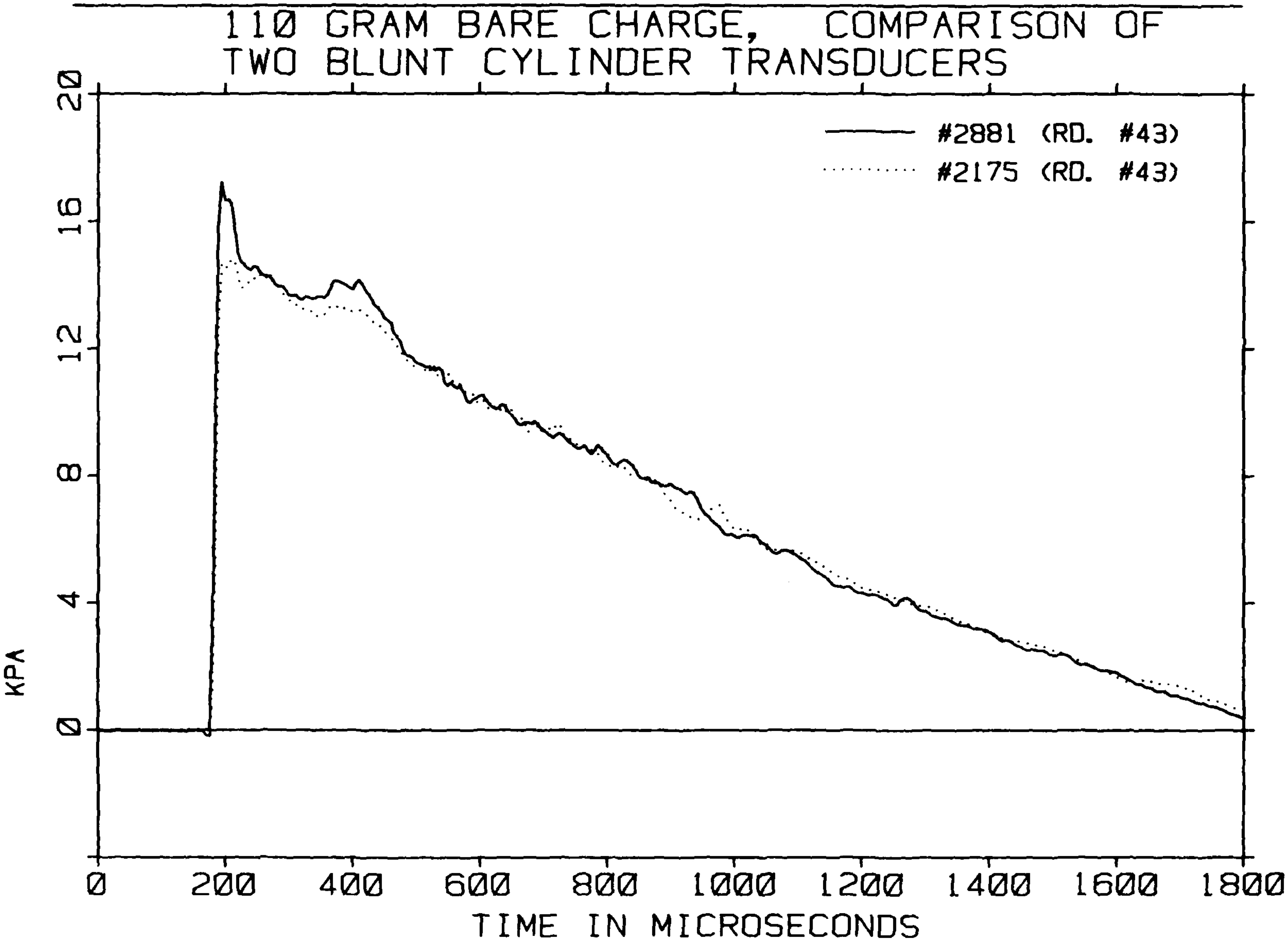

Figure 1-9. Blast overpressure from two transducers located 4 meters from 110 gram bare charge. Note 15%

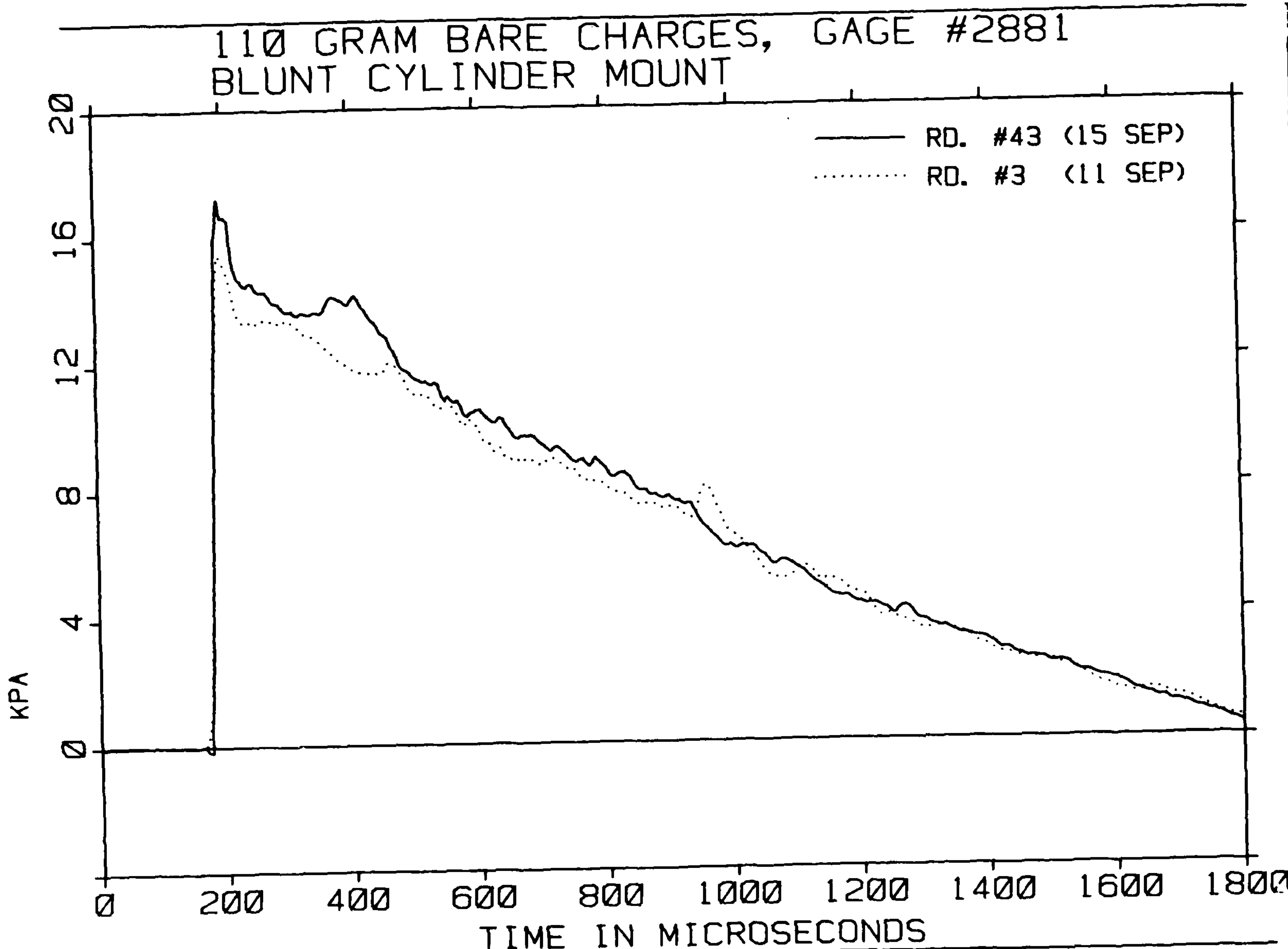

Figure 1-10. Blast overpressure from two 110 gram bare charges. Transducer was removed from tripod and replaced

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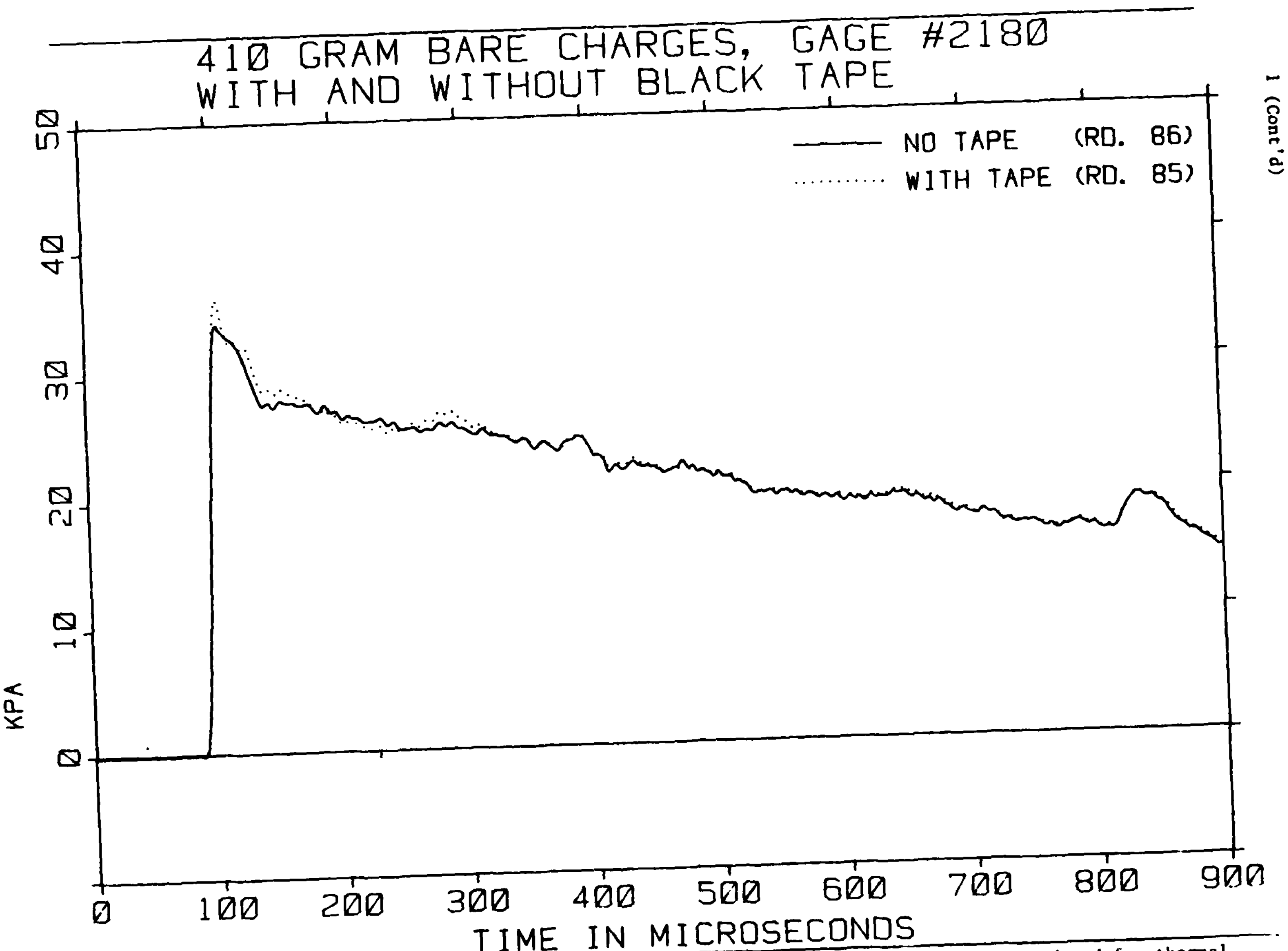

Figure 1-11. Blast overpressure from 410 gram bare charges. Note that removing black tape (used for thermal

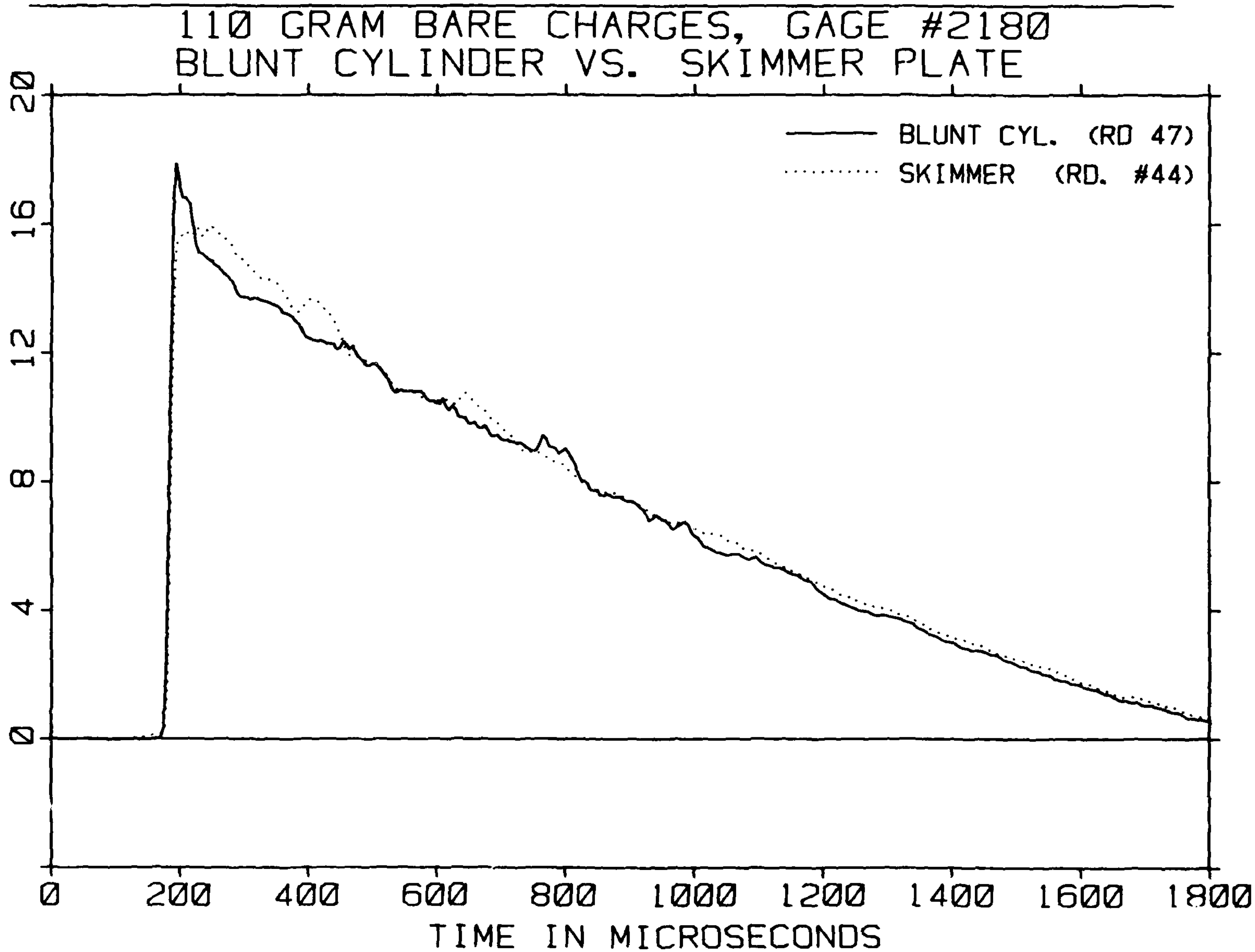

Figure 1-12. Comparison of skimmer plate mount to blunt cylinder mount. Note that skimmer plate produces lower

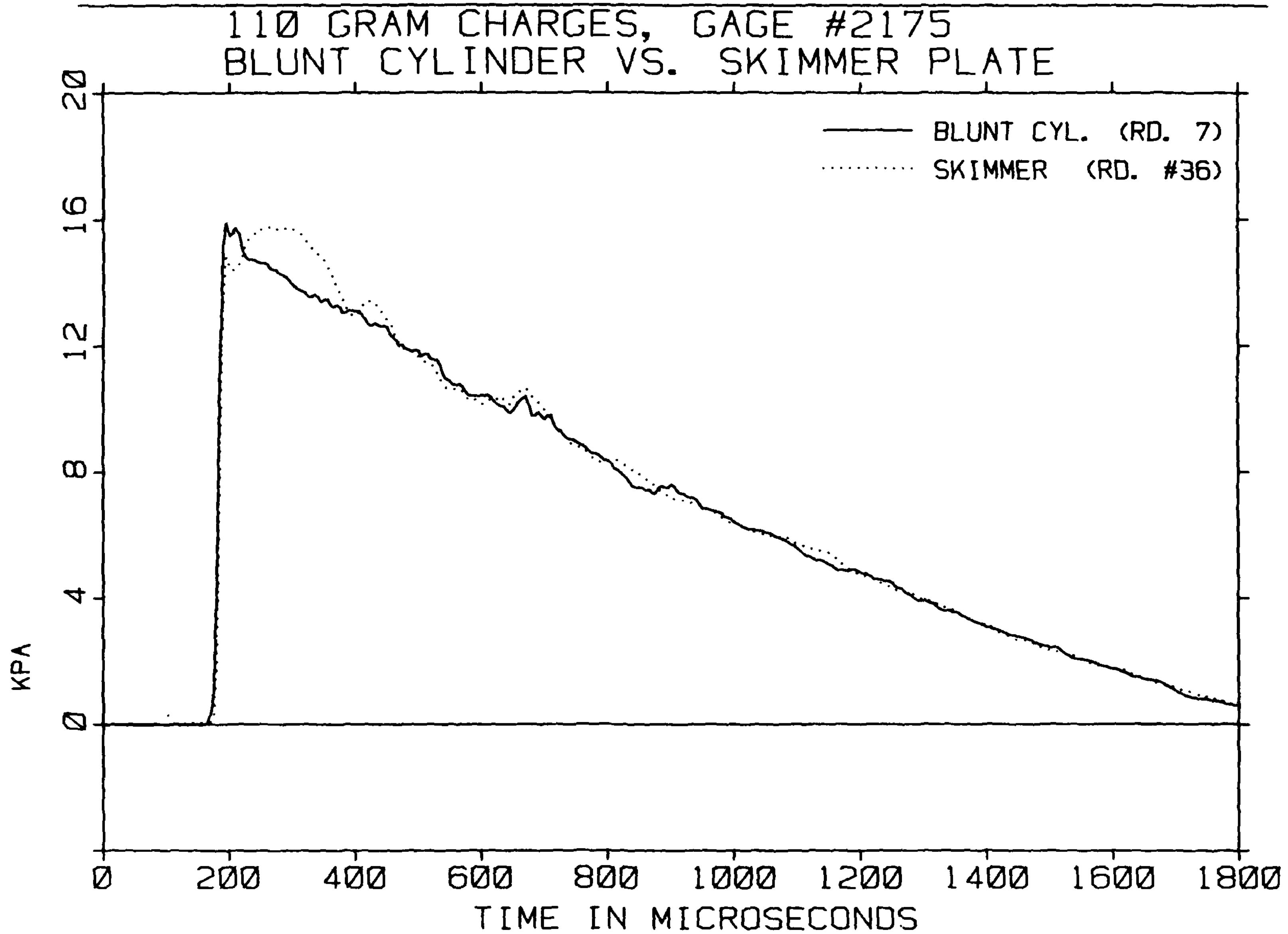

Figure 1-13. Comparison of skimmer plate mount to blunt cylinder mount. Note that peak pressures are essentially

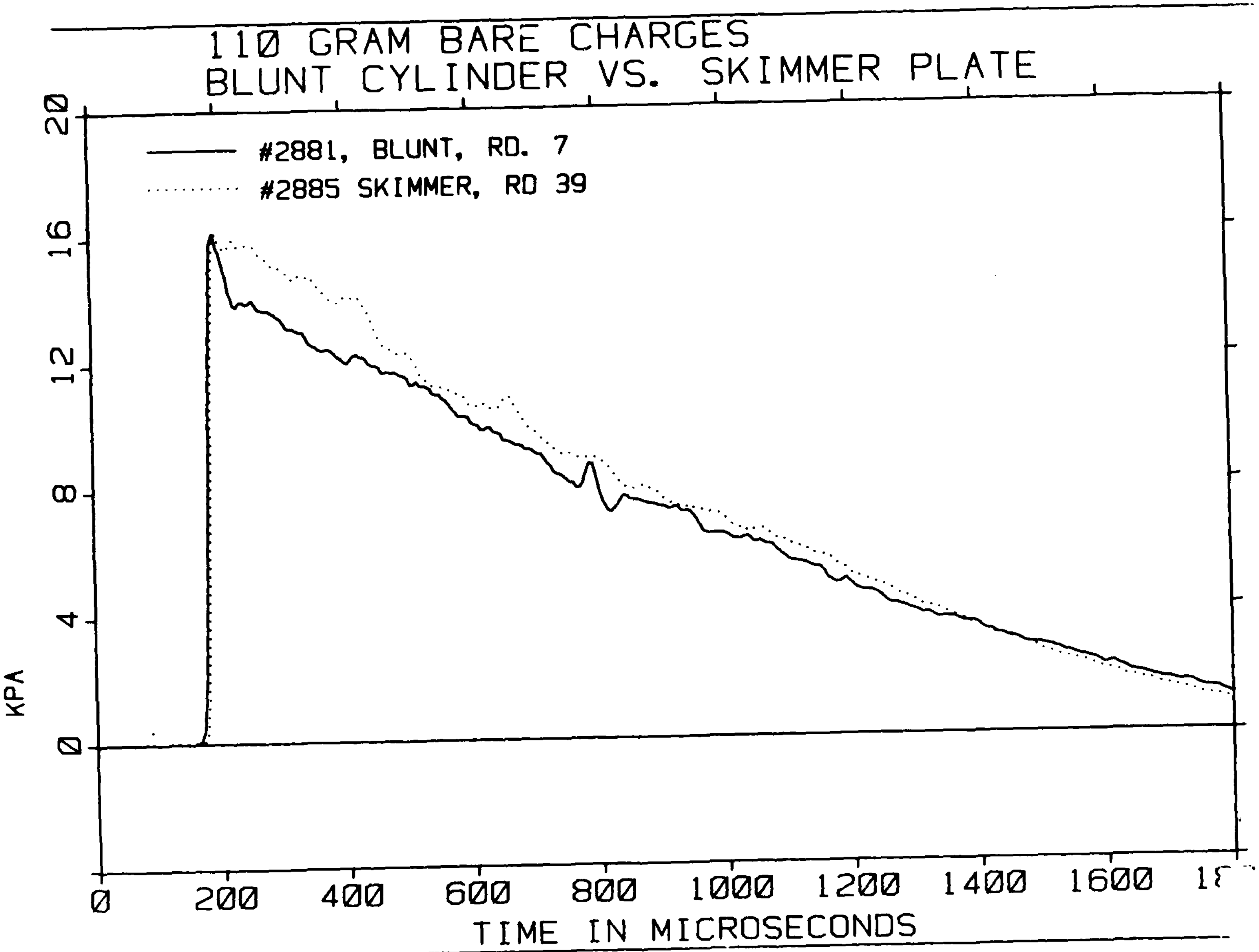

Figure 1-14. Comparison of skimmer plate mount to blunt cylinder mount using different transducers. Note

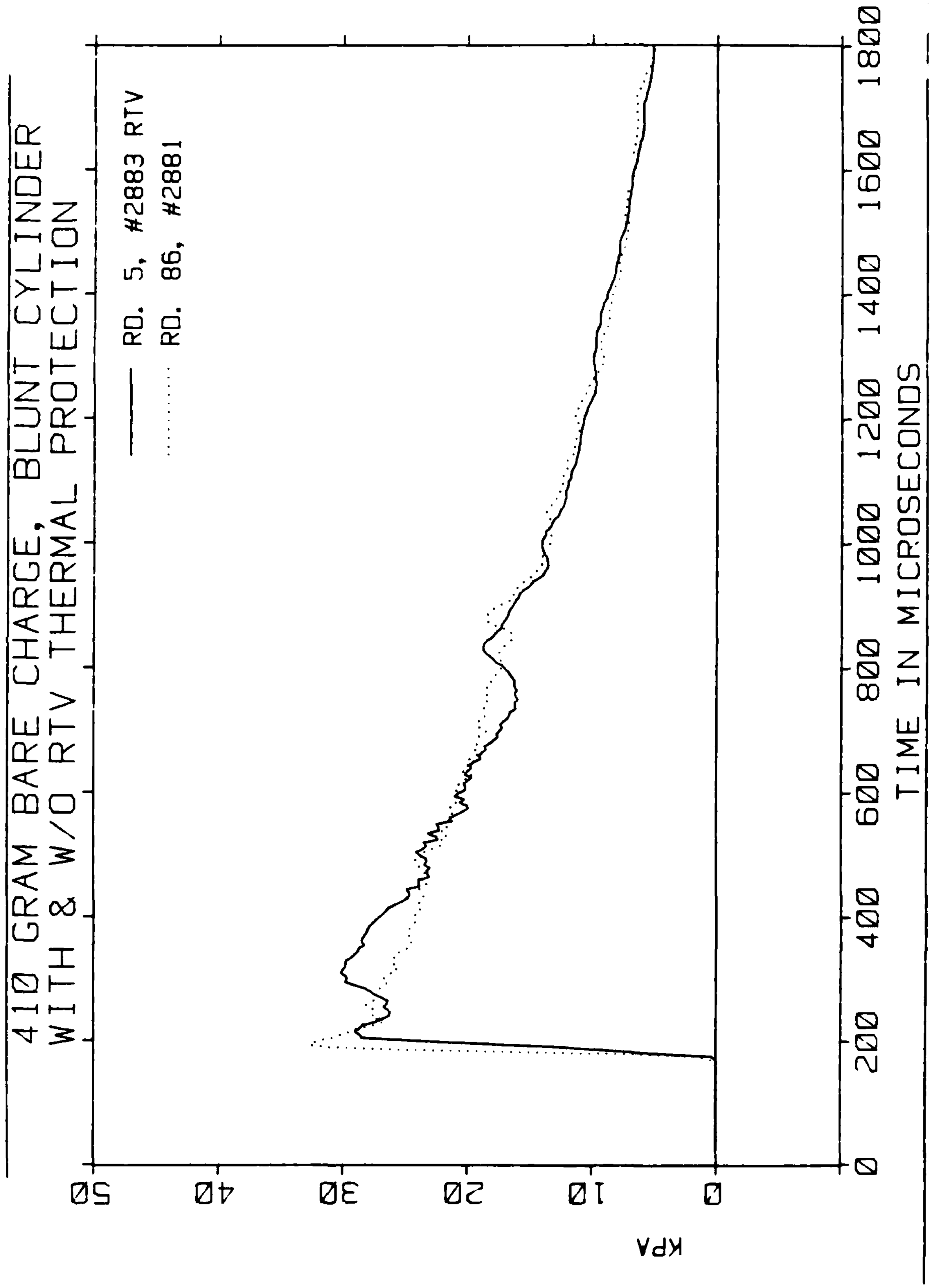

Figure 1-15. Illustration of the effect of a

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Tables 1-2 and 1-3 summarize the results of the bare charge testing. Note that the extreme spread in peak pressure (20%) is almost twice as large as the extreme spread in impulse (13%). Also note that the discrepancy between the blunt cylinder and the skimmer plate mount is more evident in peak pressure differences than in impulse differences.

TABLE 1-2. BLAST OVERPRESSURE MEASURED 4 METERS FROM 110 GRAM BARE CHARGE

	Gage No. 2175				Gage No. 2180				Gage No. 2878				Gage No. 2881				Gage No. 2882				Gage No. 2885			
Rd	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B
1					BC 18.01	-	1.7	9	-	-	-	-	BC 15.85	-	1.78	10	SP 15.83	-	1.7	9				
2									-	-	-	-	BC 15.65	-	1.79	9	SP 16.32	-	1.66	9				
3									SP 15.49	10.64	1.79	9	BC 15.51	10.91	1.79	9	BC 17.64	11.08	1.78	9				
7	BC 15.91	11.50	1.79	9					SP 15.89	11.15	1.77	9	BC 16.18	11.41	1.84	9								
36	SP 15.77	11.62	1.77	9									SP 15.71	11.51	1.77	9								
37					-	-	-	-					SP 15.71	11.65	1.80	10					SP 15.98	12.17	1.77	9
38					SP 15.75	11.61	1.71	10	SP 15.50	11.17	1.78	9					SP 15.61	11.49	1.81	9				
39	BC 14.91	11.41	1.74	9									BC 17.16	11.71	1.75	9					SP 16.16	12.11	1.81	10
40	BC 15.14	11.56	1.74	9									BC 16.68	11.53	1.75	9					SP 16.40	12.04	1.81	10
41	BC 14.88	11.44	1.76	9									BC 16.80	11.44	1.72	9					SP 16.31	12.00	1.83	10
42	BC 14.81	11.34	1.75	9									BC 17.09	11.51	1.73	9					SP 16.26	11.98	1.82	10
43	BC 14.80	11.30	1.74	10									BC 17.25	11.45	1.75	8					SP 16.36	11.81	1.82	10
44	SP 15.29	11.51	1.79	-	SP 15.95	11.65	1.76	9	BC 16.12	10.74	1.75	9	SP 15.69	11.42	1.81	9	BC 16.52	11.17	1.72	9				
45	SP 15.29	11.49	1.76	-	SP 16.03	11.57	1.74	9	BC 16.32	10.65	1.82	10	SP 15.65	11.36	1.81	9	BC 16.82	11.15	1.70	9				
46	BC 15.09	11.26	1.74	9	BC 16.52	11.14	1.74	9	SP 15.31	10.82	1.78	9	BC 17.08	11.18	1.70	9	SP 15.21	11.50	1.78	10				
47	BC 15.75	11.39	1.78	9	BC 17.84	11.33	1.74	9	SP 15.03	11.07	1.82	9	BC 16.96	11.16	1.77	9	SP 15.39	11.27	1.83	10				

Imp. = Positive phase A-impulse in kPa-milliseconds.
SP = skimmer plate.
BC = blunt cylinder.
Peak = Peak overpressure in kPa.
A = A-duration (defined in MIL-STD-1474B) in milliseconds.
B = B-duration (defined in MIL-STD-1474B) in milliseconds.

TABLE 1-3. BLAST OVERPRESSURE MEASURED 4 METERS FROM 410 GRAM BARE CHARGE

1 (Cont'd)

	Gage No. 2175				Gage No. 2180				Gage No. 2878				Gage No. 2881				Gage No. 2882				Gage No. 2885			
Rd	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B	Peak	Imp.	A	B
4					BC								BC				BC							
					34.15	26.75	2.19	10					30.54	25.35	2.18	11	35.20	25.97	2.16	10				
5					BC								BC				BC							
					34.13	26.32	2.08	10					30.52	25.30	2.22	11	35.26	25.81	2.17	10				
6	BC								BC				BC								BC			
	30.82	26.10	2.20	11					33.21	25.18	2.18	11	30.43	25.10	2.17	11					35.63	27.04	2.05	10
8	BC								SP				BC								SP			
	30.70	26.47	2.25	11					32.17	27.22	2.23	13	30.12	26.22	2.23	11					35.54	29.11	2.08	10
82	BC				SP				BC				BC				SP				SP			
	33.34	26.90	2.30	-	31.20	28.15	2.31	-	34.06	25.48	2.17	-	33.71	26.61	2.28	-	32.44	26.99	2.22	-	35.22	27.24	2.23	-
83	BC				SP				BC				BC				SP				SP			
	33.10	27.13	2.27	-	30.51	28.10	2.31	-	34.25	25.83	2.20	-	33.87	26.56	2.20	-	32.31	27.18	2.15	-	34.86	-	-	-
84	SP				BC												BC				BC			
	32.32	28.27	2.37	-	36.06	27.60	2.35	-									32.97	25.29	2.17	-	34.44	26.14	2.10	-
85	SP				BC												BC				BC			
	32.90	28.41	2.16	-	36.26	27.22	2.34	-									32.97	24.88	2.17	-	34.22	25.66	2.10	-
86					BC				BC				BC								BC			
					34.19	26.65	2.21	-	33.66	25.10	2.17	-	32.64	26.07	2.17	-					34.60	25.07	2.13	-
87					BC				BC				BC								BC			
					33.96	27.14	2.25	-	33.96	25.26	2.13	-	34.09	26.57	2.21	-					34.66	25.30	2.19	-

Imp. = Positive phase A-impulse in kPa-milliseconds
SP = skimmer plate.
BC = blunt cylinder.
Peak = Peak overpressure in kPa.
A = A-duration (defined in MIL-STD-1474B) in milliseconds.
B = B-duration (defined in MIL-STD-1474B) in milliseconds.

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2. WEAPON TESTING

Measurements were made near an 84-mm recoilless antitank weapon and a 105-mm howitzer. The measurements made by USACSTA were in accordance with the standards established by Patterson et al (encl 2, ref 6) and only the blunt cylinder mount was used.

Figure 2-1 shows transducers mounted near the 84-mm Carl Gustaf M2 recoilless rifle. Figure 2-2 shows a closeup view of the transducers and illustrates the measurement technique used to establish transducer positions.

Figure 2-3 shows the 10 measurement locations. Note that there are five pairs of positions symmetrically around the centerline of the weapon. The weapon and the transducers were located 1.52 meters (5 ft) above the ground. Table 2-1 lists the results.

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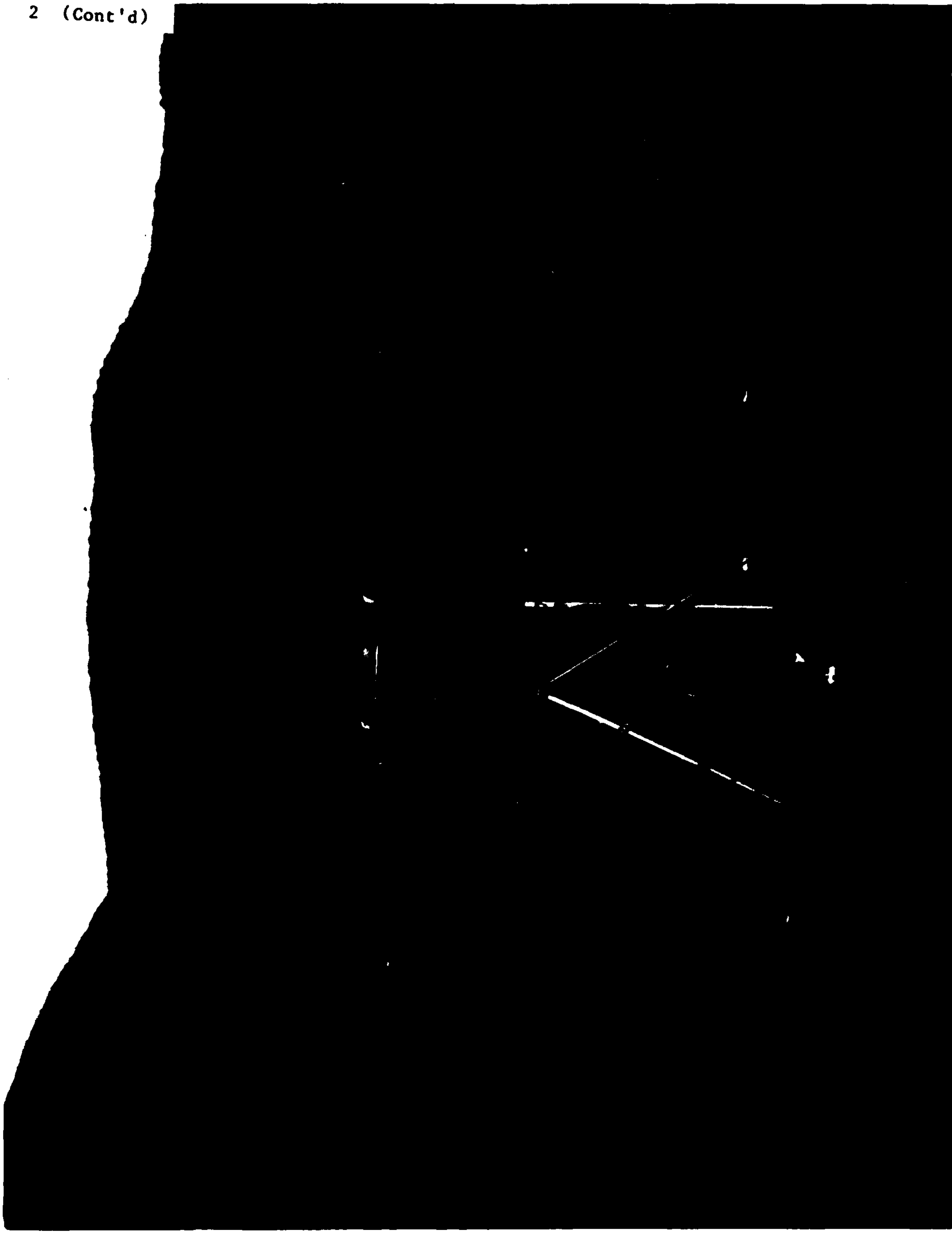

Figure 2-1. Photograph of transducers located near the 84-mm Carl Gustaf antitank weapon.

Figure 2-2. Closeup of transducers near the 84-mm Carl Gustaf antitank weapon, showing technique used to locate transducer position.

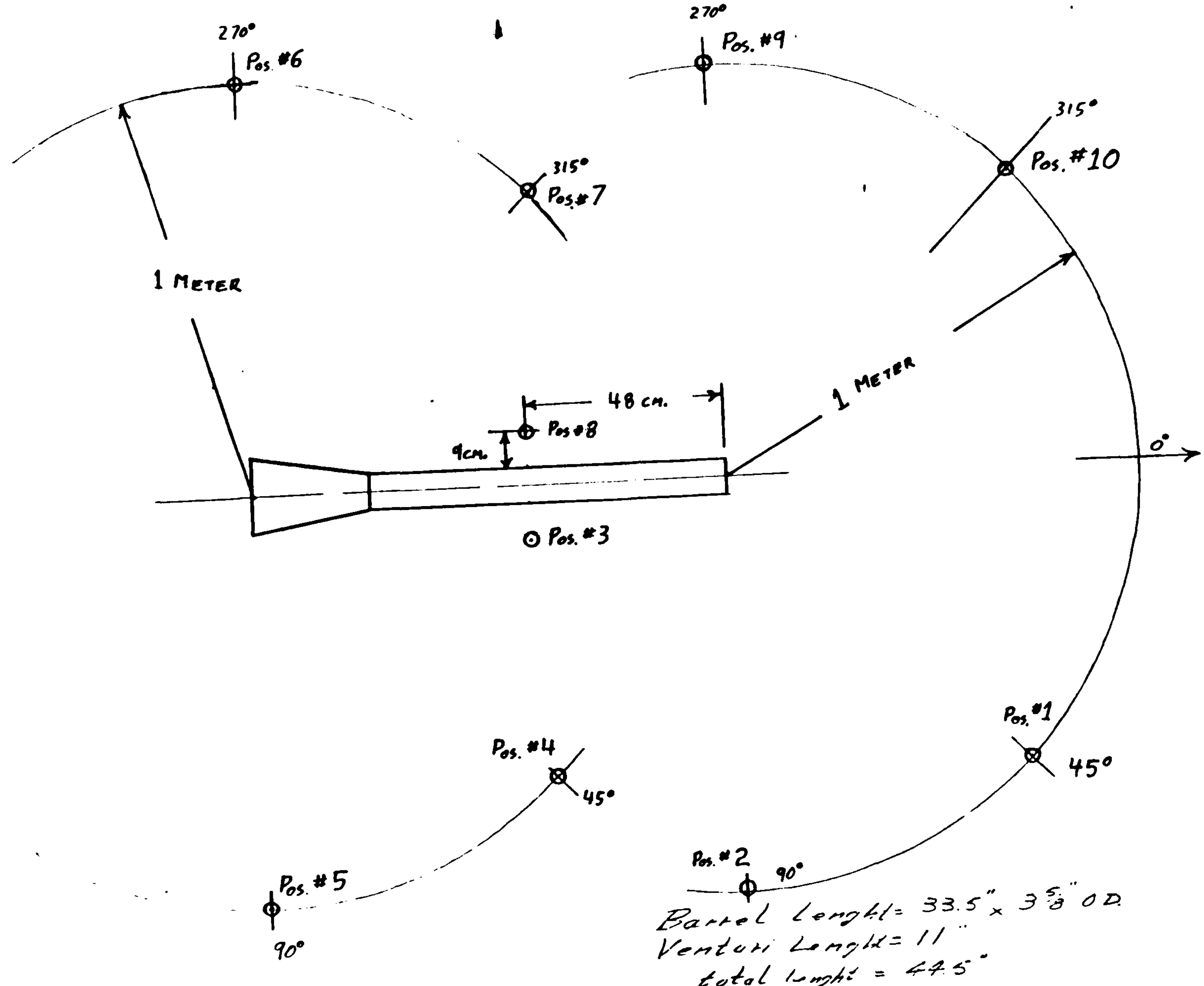

Figure 2-3. Location of measurement positions near the 84-mm Carl Gustaf antitank weapon. Weapon centerline and all transducers located 1.52 meters above the ground.

TABLE 2-1. BLAST OVERPRESSURE AT VARIOUS POSITIONS NEAR THE 84-MM CARL GUSTAF ANTITANK WEAPON

Position No.	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B
	Round 11			Round 12			Round 13			Round 14			Round 15			Mean		
2	24.34	1.47	12	36.78	1.54	11	24.06	1.97	12	26.81	3.78	13	38.04	1.23	11	30.01	2.00	12
9	26.41	1.47	12	33.46	3.35	12	27.86	2.06	11	25.34	2.21	13	25.31	2.03	11	27.68	2.22	12
	Round 16			Round 17			Round 18			Round 19			Round 20			Mean		
3	31.42	1.84	14	24.86	1.94	14	19.86	2.27	15	19.84	2.39	14	26.34	3.72	15	24.46	2.43	14
8	24.19	1.91	14	22.53	1.88	15	24.05	1.94	14	19.43	2.17	14	19.72	2.78	14	21.98	2.14	14
	Round 21			Round 22			Round 23			Round 24			Round 25			Mean		
4	24.95	0.63	-	22.04	0.67	-	22.53	0.57	17	18.98	1.14	14	21.14	2.24	14	21.93	1.05	15
7	19.60	0.53	16	20.33	2.16	14	24.43	3.51	14	20.57	1.21	14	20.19	1.23	14	21.02	1.73	14
	Round 26			Round 27			Round 28			Round 29			Round 30			Mean		
1	35.29	1.88	10	32.21	1.59	11	32.43	1.27	10	33.17	1.22	10	35.37	1.60	10	33.69	1.51	10
10	32.42	1.87	11	32.00	1.69	10	33.36	1.94	11	31.51	1.33	10	29.29	1.40	11	31.72	1.65	11
	Round 31			Round 32			Round 33			Round 34			Round 35			Mean		
5	90.46	1.29	6	57.26	1.53	9	76.64	1.36	7	84.18	0.94	6	76.47	0.76	9	77.00	1.18	7
6	65.51	0.84	10	71.89	0.88	8	74.75	0.75	7	73.29	0.94	7	77.91	0.83	7	72.67	0.85	8

Peak = Peak overpressure in kPa.
A = A-duration (defined by MIL-STD-1474B) in milliseconds.
B = B-duration (defined by MIL-STD-1474B) in milliseconds.

Figure 2-4 shows the blast overpressure in the operator position. Note that this measurement (peak = 24.86 kPa = 181.9 dB, B = 14 ms) exceeds the current US Army human tolerance level specified by the Z curve of MIL-STD-1474B (encl 2, ref 7).

Figure 2-5 shows the arrival time of blast overpressure at the five different positions. Figure 2-6 shows the initial overpressure at position No. 5 of three successive rounds. Large round-to-round variations in peak pressure were observed at position No. 5. As shown in the plot, these variations appear to be caused by differences in arrival time of two shock waves.

Measurements were also made near the 105-mm L5 pack howitzer firing high explosive projectiles with charge 7 and elevated to 740 mils.

Figure 2-7 shows the 10 measurement locations. Note that, once again, there are five pairs of positions located symmetrically around the centerline of the weapon. Positions 2 and 9 represent the location of a kneeling crew member and transducers at these positions were located 1 meter above the ground. At all other positions, the transducers were located 1.52 meters above the ground.

The results are tabulated in Table 2-2. The highest overpressures were obtained at positions 1 and 10. Note that the example shown in Figure 2-8 (peak = 47.62 kPa = 187.5 dB, B = 13 ms) clearly exceeds the Z-curve of MIL-STD-1474B.

Also note that the measurements at locations 1 and 10 are significantly different, even though these positions are in symmetric positions. This discrepancy became more pronounced as the test progressed because the weapon moved slightly to the left (toward position 10). This large change in overpressure caused by a small change in position indicates that a significant gradient is present in this portion of the overpressure field.

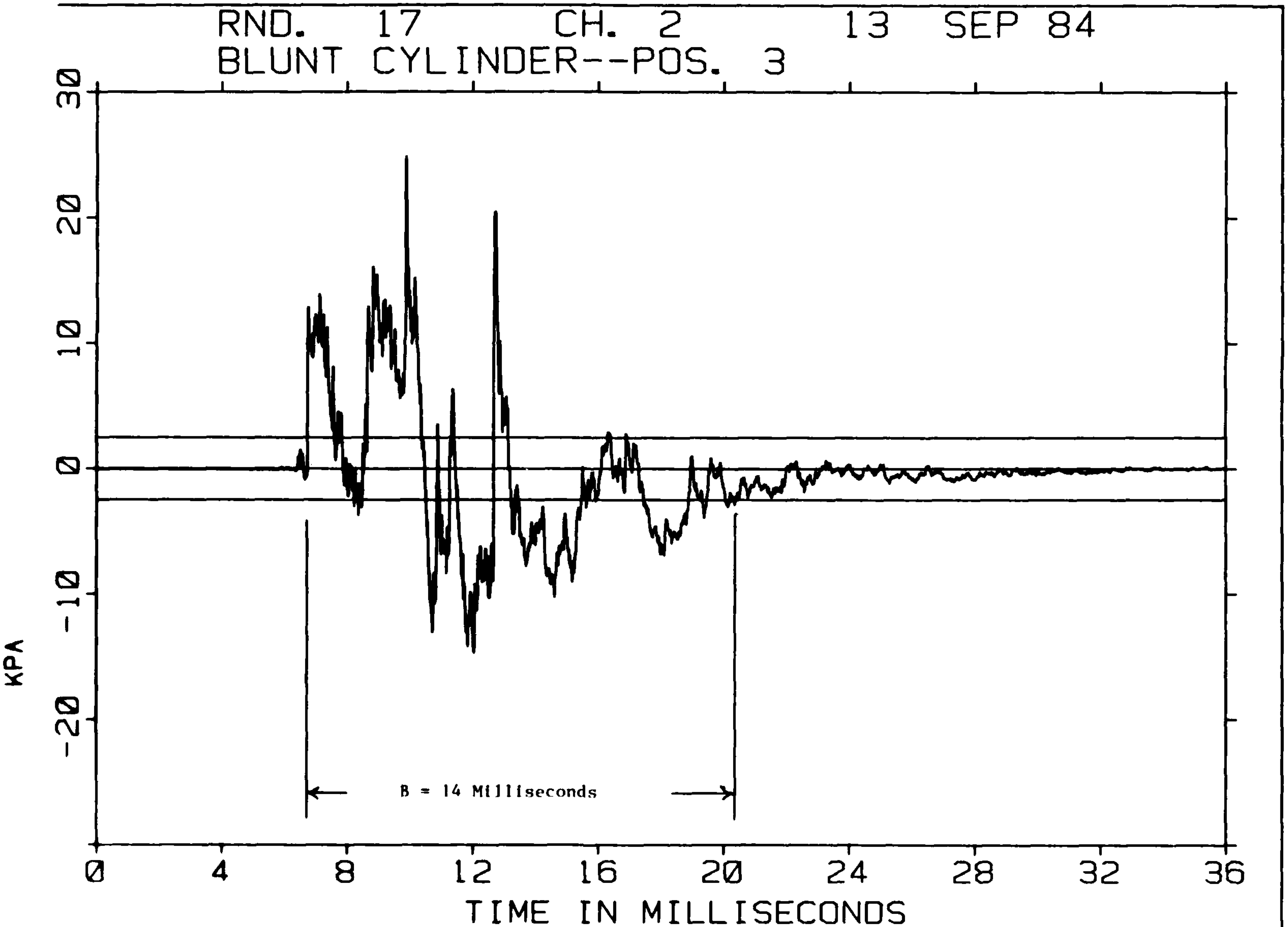

Figure 2-4. Blast overpressure in the operator position of 84-mm Carl Gustaf antitank weapon. Note that

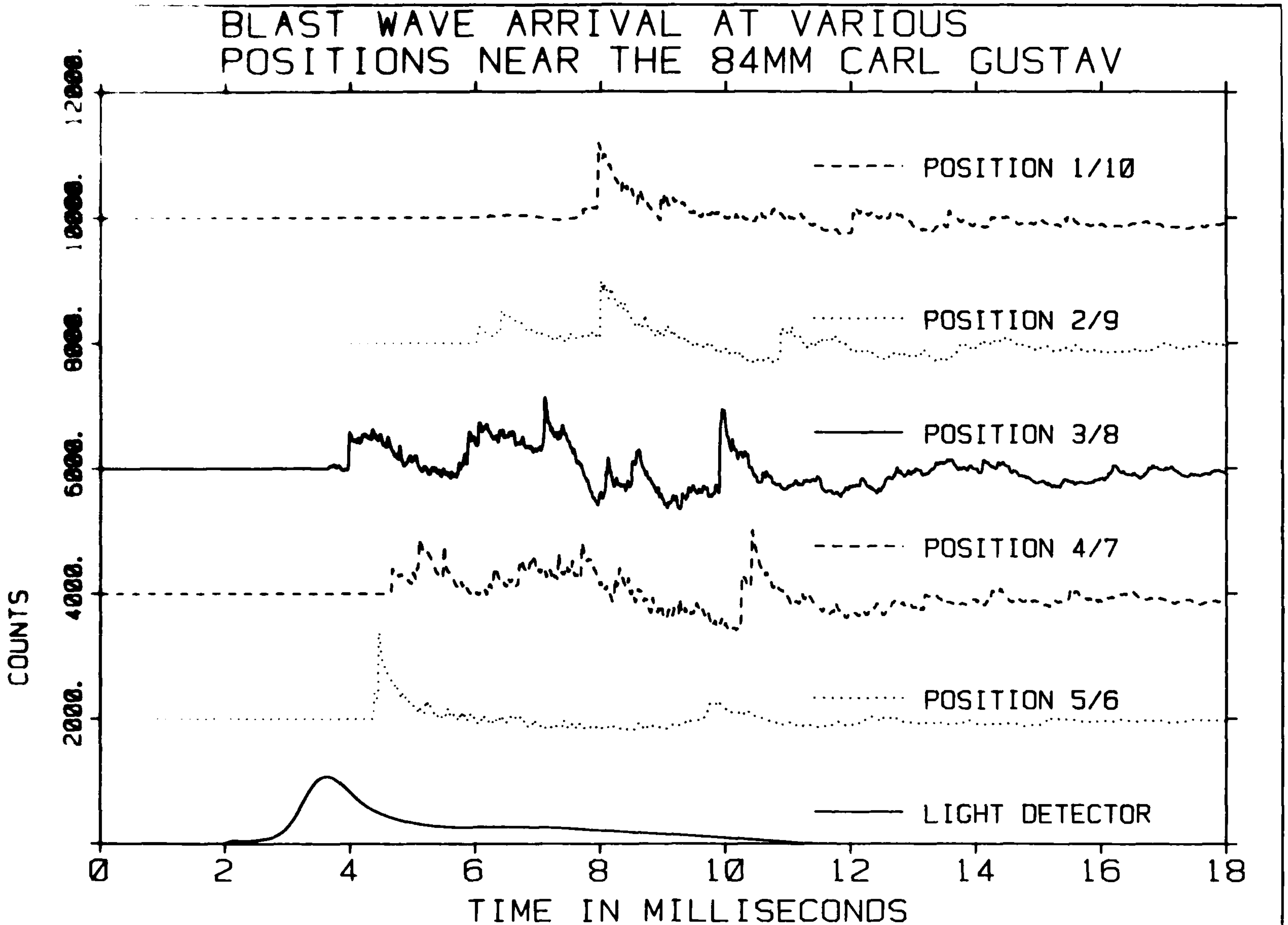

Figure 2-5. Blast overpressure at various positions near the 84-mm Carl Gustaf antitank weapon. Note that blast arrives at operator position (positions No. 3 and 8) first.

2 (Cont'd)

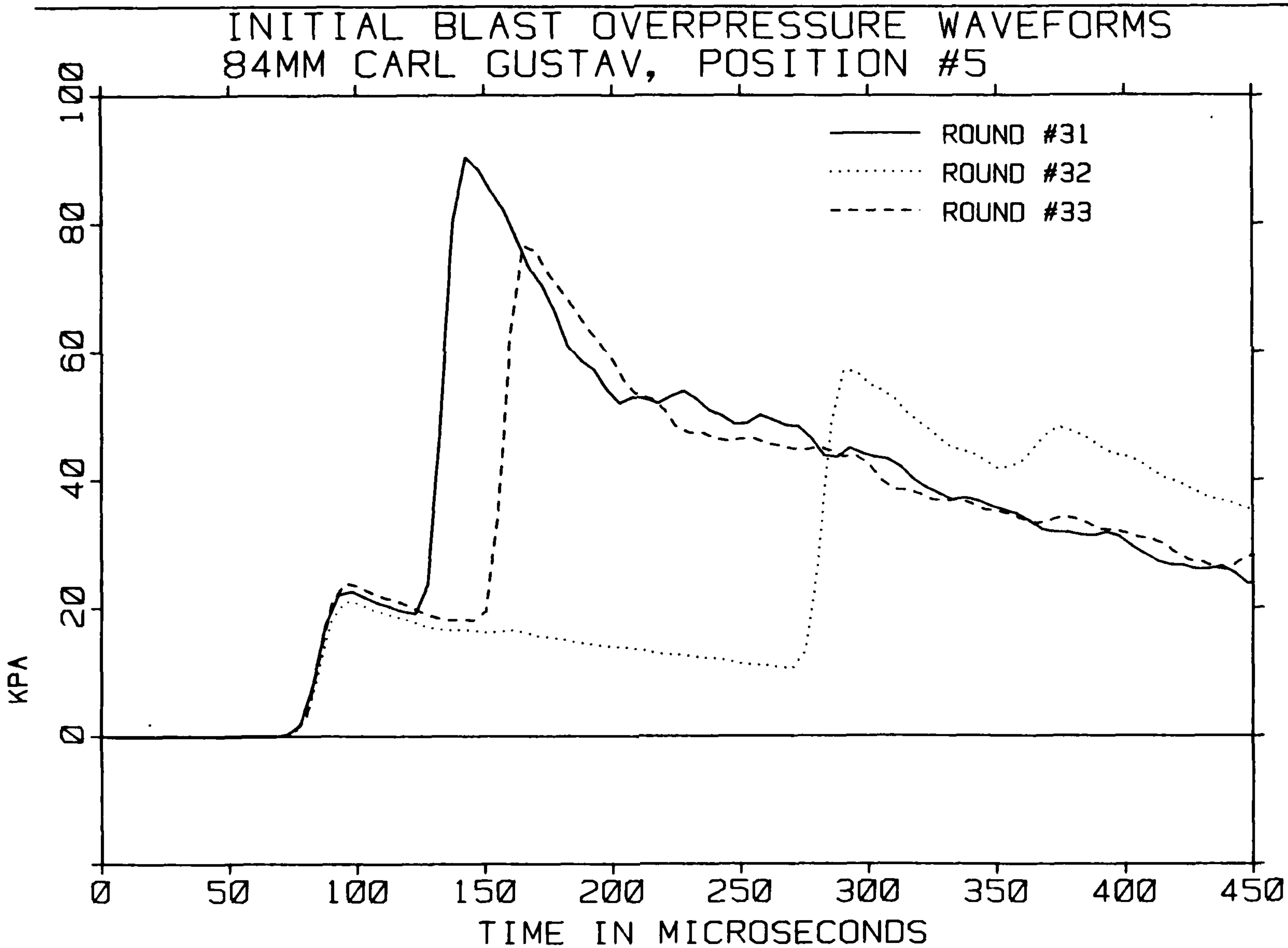

Figure 2-6. Initial blast overpressure at position No. 5. Notice that change in arrival time of second

2 (Cont'd)

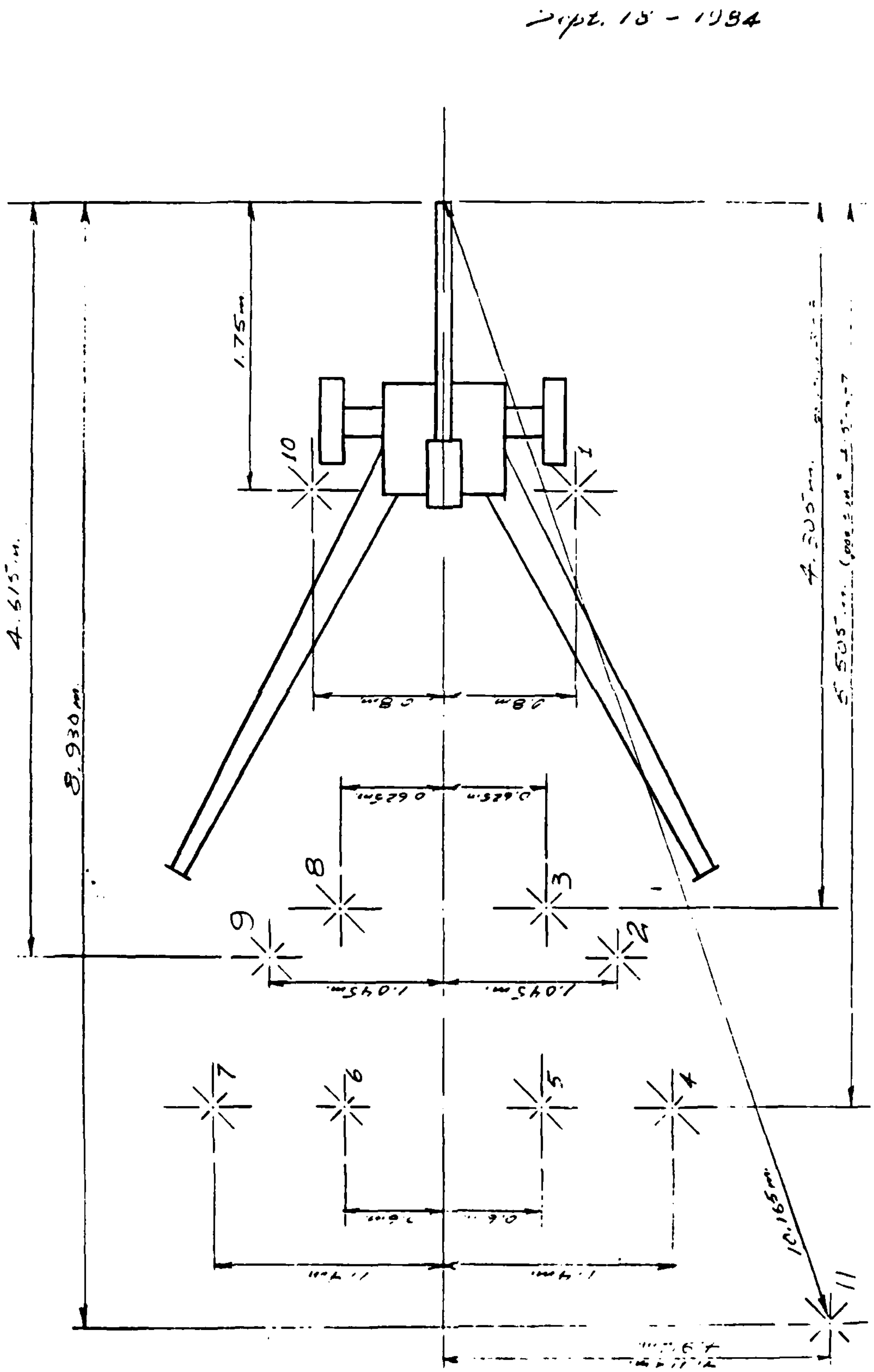

Figure 2-7. Measurement positions near the 105-mm L5 howitzer. Transducers at positions No. 2 and 9 were located 1 meter above the ground. All other transducers were located 1.52 meters above the ground.

TABLE 2-2. BLAST OVERPRESSURE AT VARIOUS POSITIONS NEAR THE 105-MM L5 HOWITZER (CHARGE 7)

2 (Cont'd)

Position No.	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B	Peak	A	B
	Round 56			Round 57			Round 58			Round 59			Round 60			Mean		
2	10.17	4.65	19	11.51	4.49	18	10.75	2.29	17	11.33	3.85	16	10.93	3.97	17	10.94	3.85	17
9	10.72	4.36	18	10.10	4.13	24	10.63	4.12	18	10.97	4.47	16	10.52	4.32	16	10.59	4.28	18
	Round 61			Round 62			Round 63			Round 64			Round 65			Mean		
3	14.53	2.59	13	14.75	2.88	14	14.54	2.72	14	15.45	2.03	13	14.79	2.43	14	14.81	2.53	14
8	15.21	2.76	14	13.55	2.83	17	14.05	2.04	16	14.23	2.11	17	12.92	2.73	17	13.99	2.49	16
	Round 66			Round 67			Round 68			Round 69			Round 70			Mean		
4	8.89	2.59	13	9.04	2.12	18	10.02	2.15	17	8.98	1.77	17	9.54	4.56	14	9.29	2.64	16
7	7.84	2.76	14	7.79	5.09	19	9.34	2.19	17	7.65	4.42	17	7.80	2.18	17	8.08	3.33	17
	Round 71			Round 72			Round 73			Round 74			Round 75			Mean		
5	10.96	2.11	14	10.55	2.29	14	9.63	2.45	14	10.00	2.31	14	11.23	1.87	16	10.47	2.21	15
6	9.26	2.59	17	10.91	1.84	16	9.94	1.92	17	9.27	2.57	17	9.58	2.39	17	9.79	2.26	17
	Round 77			Round 78			Round 79			Round 80			Round 81			Mean		
1	47.62	1.76	13	45.09	2.13	13	49.00	1.90	13	47.68	1.70	13	44.35	2.00	13	46.75	1.90	13
10	58.91	1.13	12	56.93	1.58	13	53.30	1.57	13	57.76	1.41	12	53.57	1.69	13	56.09	1.48	13

Peak = Peak overpressure in kPa.
A = A-duration (defined by MIL-STD-1474B) in milliseconds.
B = B-duration (defined by MIL-STD-1474B) in milliseconds.

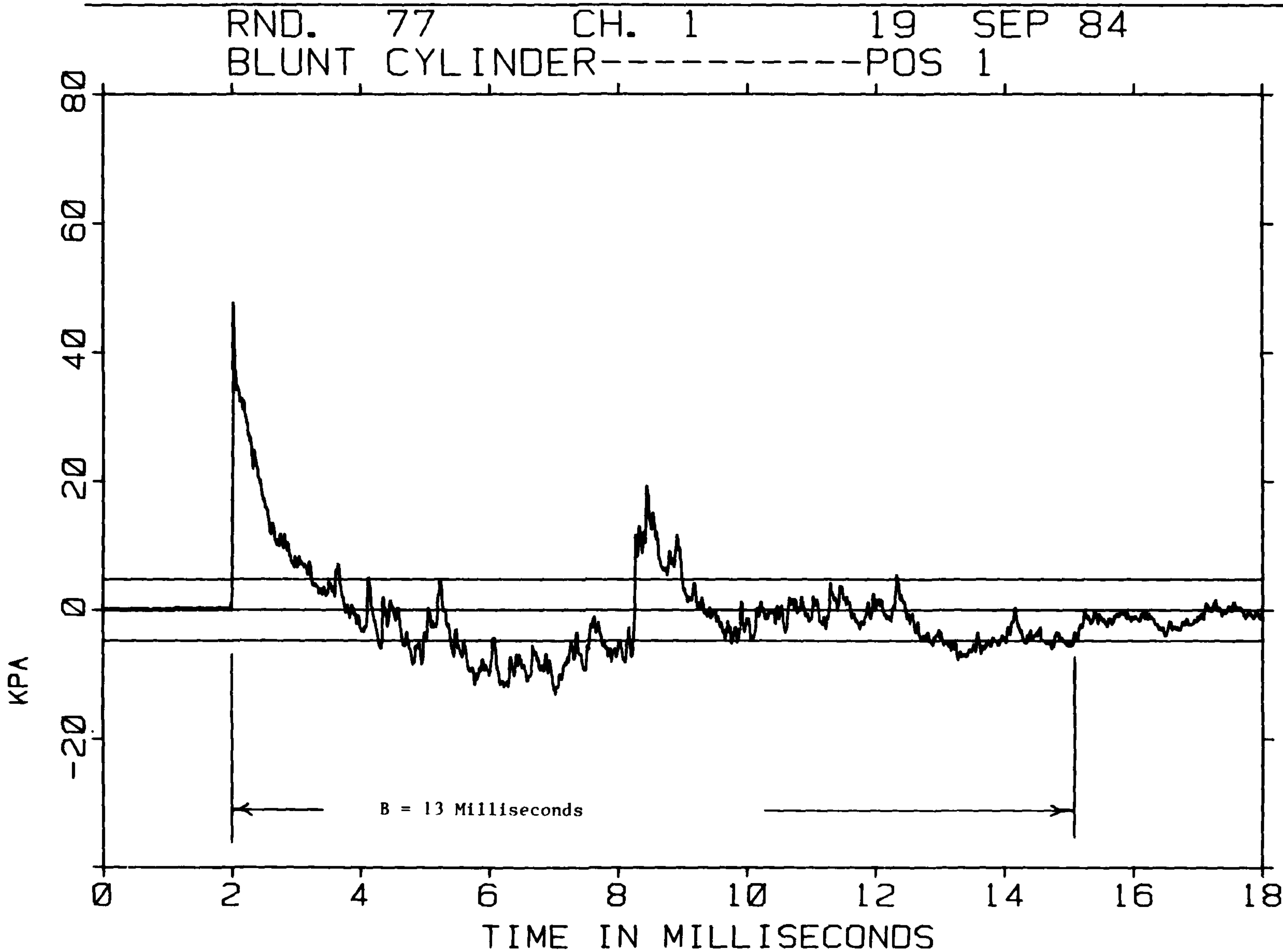

Figure 2-8. Blast overpressure at assistant gunner position of the 105-mm L5 howitzer firing charge 7. Note that this level (47.62 kPa, B = 13 ms) exceeds the Z curve of MIL-STD-1474B.

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